Manifold Compositions and the Evolving Entity

Prof. Sever Tipei, DMA
Computer Music Project, University of Illiinois
http://cmp.music.illinois.edu/people/tipei/
e-mail: s-tipei@illinois.edu

1. Introduction

Frozen approximations of actual music, musical scores are also sets of instructions that can generate a multitude of aural renditions. Unlike deterministic computer programs whose outputs are the same every time, the score is an engenderer of human interpretations. Even distinct renditions of a musical work by the same performer will be slightly different on separate circumstances but the variance will be barely perceptible, if at all recognizable. However, performances of the same work by two individuals will display divergences that attentive listeners will be able to detect. By the same token, jazz musicians improvising on the same tune will produce different outcomes on separate occasions.

At a higher level, it is easy to observe that there are not two Bach fugues or Mozart sonatas with the exact same architecture although, within each category, they share some fundamental structural characteristics. During each historical period musical "forms" like fugue, sonata, variations, etc. have been used to compose myriad works belonging to such categories. Only that these "forms" are not stagnant, vapid schemes, but malleable matrices begetting discrete entities - at least in the hands of decent composers.

2. Open works, aleatory music and composition classes

In the late 1950s, a series of works had appeared in which the performer was asked to contribute to either the "form" or to details of these aleatory compositions. In the definition of Werner Meyer-Eppler, an aleatory (*Aleatorik*, a noun in German) process "is determined in general but depends on chance in details" [1]. Aleatory pieces are based on a shared structure and each outcome is an actualization, controlled by the performer, of a potential offered by the composer. As an example, Karlheinz Stockhausen's *Klavierstücke XI* [2] contains nineteen fragments rigorously written in their details that the pianist is asked to perform in any order; the piece ends when a fragment is played for the third time. It can be compared to Alexander Calder mobile sculptures since like them all possible arrangements of the parts are equally acceptable. Writing about it and about similar pieces in his seminal *Opera Aperta* (later the first chapter of *The Role of the Reader*), Umberto Eco quotes Henri Pousseur who describes one of his works: "*Scambi* is not so much a musical composition as a <u>field of possibilities</u>, an explicit invitation to exercise choice" [3].

Plus-minus, also by Stockhausen, goes one step further [4]. In it, seven pages of symbols and seven pages of musical materials (vertical aggregates and secondary ornaments) may form pairs containing one page from each category. Neither the number of performers nor the instrumentation are specified and not all the pages have to be used. The work is a process during which materials are accumulated or depleted and when their numbers become negative, non-pitched events are introduced. *Plus-minus* is an elaborate and strict structure leading to a unlimited number of possible realizations.

Similar although less stringent or complex processes are spawned by graphic scores, based on drawings or other visual means, text compositions (Textkomposition) or even conceptual music exploits. The appellation c*omposition classes* characterizes all of them: equivalence classes which contain multiple versions realized according to an abstract template. Each of them is a set or a class of congruent virtual incarnations of a meta-musical archetype. A famous literary attempt, Stéphane Mallarmé's *Le* <<*livre*>> [5], suggests an analogous project.

3. Manifold compositions

A subset of the composition class category, a *manifold composition* comprises all actual and potential variants of a musical work generated by a computer that

1. runs a program containing elements of indeterminacy
2. reads essentially the same data for each variant

A unlimited number of works belonging to the same equivalence class can be produced in this way. The members of a *manifold composition* are variants of the same piece; they share the same structure, pitch, rhythmic materials, amplitudes, spectra, etc. and are the result of the same process, but differ in the way specific events and diverse sound characteristics are distributed in time. Like faces in a crowd, they all have common basic features but exhibit particular attributes due to the fact that different seeds for the random number generator result in different outputs. They are somewhat similar to the serigraphs produced by a visual artist, or to Andy Warhol *Campbell's Soup Can* series [6], except that individual members of the manifold could be even more distinct from one another.

Attempts at employing computers to engender families of works are exemplified by three notable early undertakings due to Iannis Xenakis, Gotfried Michael Koenig and Lejaren Hiller. The ST family of pieces composed by Xenakis were generate in early 1960s with his *Free Stochastic Music* program written in FORTRAN and running on an IBM 7090. They include works for string quartet (ST/4), chamber ensembles (ST/10) and orchestra (ST/48). Koening's *Segmente*, for small chamber ensembles were composed using his *Project 1* and *2* algorithmic composition programs in between 1960s and 1980s along with other pieces. *Algorithms I* through *III* for larger ensembles and electronics, were written by Hiller in late 1960s with the MUSICOMP program using SCATRE and FORTRAN languages.

In the first two examples above, only one composition program was used to generate fragments of music (later re-arranged in the case of the ST series) but the input data was modified from piece to piece. Hiller employed two separate programs, one for the assisted-composition part and another one, written by Gary Grossman, for sound synthesis; the code was modified to deliver separate "versions" of each movement. By contrast, in the production of manifolds, composition and synthesis are combined in a uninterrupted operation, the input does not change from variant to variant and each version is generated in its entirety, without interruptions.

As previously mentioned, when elements of indeterminacy are included, random number generator seed changes results in new pieces. An persuasive situation ensues if some sections of the work are fixed, designed to remain unchanged while others are modified. In the following example, the A.N.L.-folds, a short manifold composition, three out of a total of eight sections remain basically the same in all versions: a beginning chord, its retrograde at the end, and a short jingle, the fourth section, in the middle. They are the unchanged pillars that anchor the other sections. The fifth section, a grainy sound mass type of texture, preserves its character every time but individual attacks and pitches are always different although this is difficult to recognize in the thick texture. The remaining sections, 2-3 and 6-7, emphasize, respectively, tremolo/vibrato and transients of frequency/amplitude. The density of the 2-3 group is lower than the density of the 6-7 group. They can switch places as far as their content goes but the density remains attached to the section number. The overall density of the piece may also vary between 200 and over 500 sounds.

C	m	m	**C**	***G***	m	m	
H	o	o	**H**	***R***	o	o	**C**
O	b	b	**I**	***A***	b	b	**H**
R	i	i	**M**	***I***	i	i	**O**
D	l	l	**E**	***N***	l	l	**R**
	e	e		***Y***	e	e	**D**
1	2	3	4	5	6	7	8

table 1 A.N.L.-sections

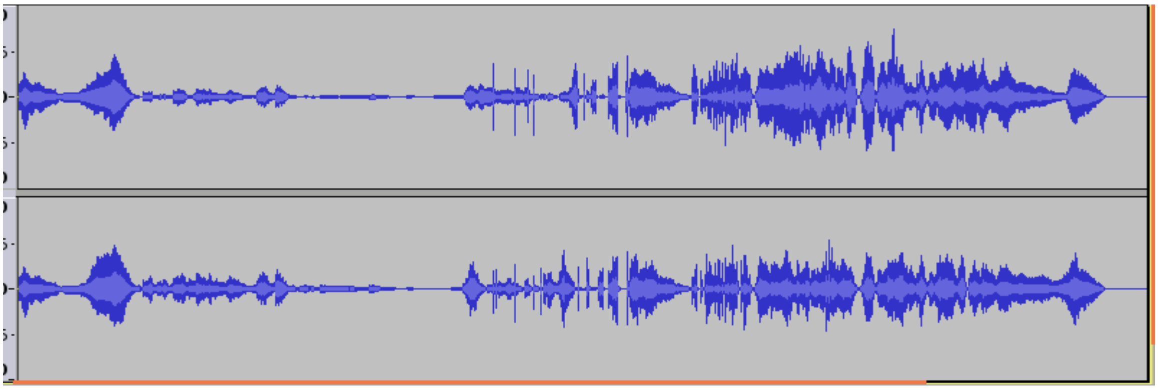

figure 1. A.N.L.-folds variant

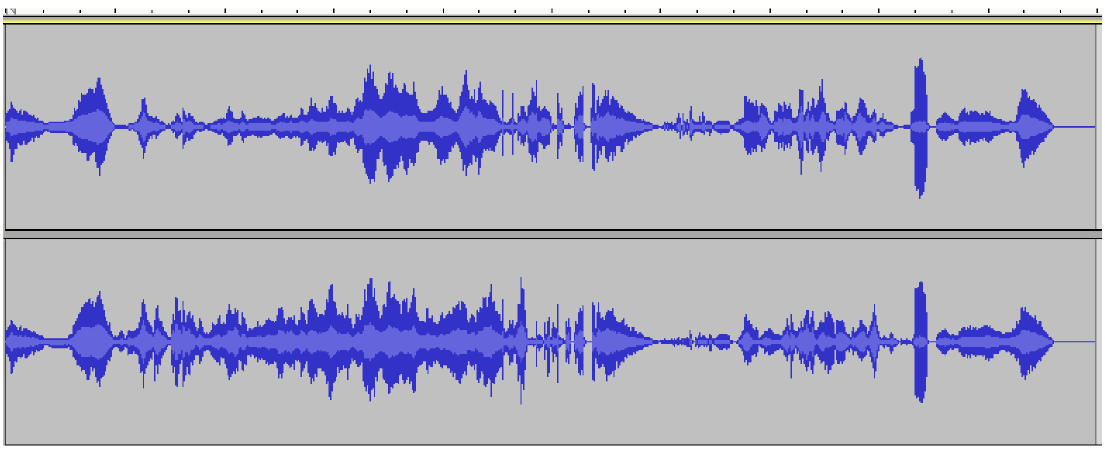

figure 2. Another A.N.L.-folds variant

Even in the case of the fixed sections (1, 4, and 8), minute details of each sound's makeup are bound to fluctuate with every rendering due to the indeterminacy present at all levels of both composition and sound synthesis. In spite of such differences, the outcomes are easily recognized as the **same piece** due to the permanence of the unchanging sections and to the general architecture of the work.

Manifold compositions represent an idiomatic way of using computers in music composition by mass producing unique versions of an archetype. It is stipulated that a version should not be performed in public more than once, thus stressing the ephemeral quality of any musical activity and preventing it to become a commodity.

4. DISSCO

A tool for generating manifolds, DISSCO, Digital Instrument for Composition and Sound Synthesis, represents a unified, seamless approach to composition and sound design. Written in C++, it consists of three main modules: CMOD, the composition module, LASS, a library for additive sound synthesis and a graphic user interface, LASSIE.

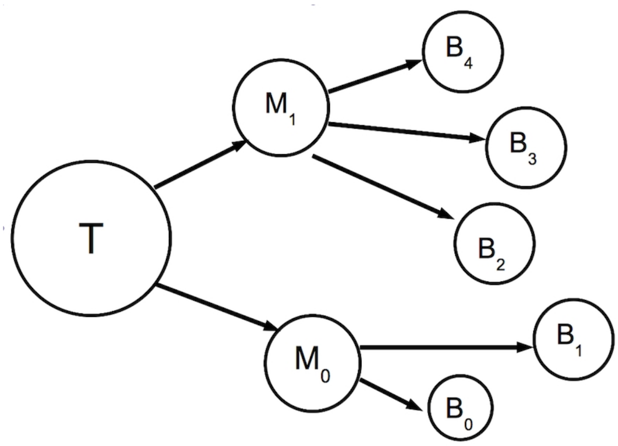

figure 3. DISSCO structure as a rooted directed graph. Only one intermediate level is shown.

CMOD events form a rooted directed graph, a tree structure, with the TOP event the entire piece, HIGH, MEDIUM and LOW events intermediate sections and subsections while individual sounds are built in the BOTTOM type sections. Like Russian dolls, each type may contain events of less structural importance. Parent-child relationships pervade this arrangement and all events have a start time, duration and type while the more complex BOTTOM events also assign frequency, loudness, AM, FM, transients, placement in space and reverberation to individual sounds.

A central premise in DISSCO is that the same kind of operations can be applied at different time scales from the entire piece, its sections and sounds, down to modifiers of frequency and amplitude (FM, AM) and to frequency itself. Such a hierarchy is based on "time intervals" of decreasing "magnitude", to paraphrase Stockhausen [7].

The UTILITIES class provides access to both deterministic and random procedures. First category contains ways to select precisely defined elements according to various choosing procedures, patterns or sieves. Sieves are logical filters, first introduced by Xenakis, that use modulo and Boolean operations to select items from a ordered continuum and serve to construct pitch scales or rhythmic templates. The second category includes random or stochastic distributions and Markov chains.

Like the programs of Hiller, Xenakis and Koenig, DISSCO is a comprehensive or autonomous software, that does not require or allow the intervention of the user once the computations have started. It delivers a final product which does not necessitates further adjustments. It is a “black box” meaning that it reads in the data provided by the user and outputs a finished object, the piece, in a uninterrupted process. This is necessary in order to preserve the integrity of the operation - modifying the results or intervening during the computations would amount to the alteration of the data or of the logic embedded in the software, i.e. a falsification of the experiment. It produces manifolds whose variants are equally valid: similar to the case of aleatory compositions or to Mallarmé's project, there is no room for prejudicial opinions. The result might be surprising but, if the logic and the code are correct, it has to be accepted. Or, as Herbert Brün once said about being surprised by the outcome: *"I didn't learn how to like my new piece yet".* The difference between preferring "those events to happen that one wants to hear" vs. choosing "to hear those events one wishes would happen" [8] characterizes an experimental attitude which has aesthetic and political consequences - DISSCO along with the manifold undertaking share it.

5. Evolving Entity

Evolving Entity is an ongoing project that builds on the manifold concept and uses DISSCO. After a variant of the piece is produced, if the computations continue for an arbitrary length of time without interrupting the initial sequence of random numbers, a time ordered array of equivalent but distinct pieces is created. The unbroken string of random numbers insures the enduring identity of an Entity which changes in time. Every so often the user may take samples to see and hear what the Entity (the piece) looks and sounds at a given moment.

Another possibility is to play back continuously the results and create an installation: akin to a fountain, it would have a stable configuration, always the same, but would exhibit new details every time. Depending on its complexity and on the length of time during which it would be displayed, a high performance computer might be needed to generate the music in real time.

The transformations taking place during iterations can be evaluated and controlled and the main tool used to insure that this is done as objectively as possible is Information Theory. *Shannon entropy* or the amount of **Information** in a discrete random variable is

$$H = -\sum p_i * \log_2 p_i \qquad \text{for } i = 1 \text{ to } n$$

and (1)

$$H_{max} = \log_2(n) \qquad \text{for equiprobable cases}$$

The relative information, H_i / H_{max} corresponds to **Originality** in a piece of music and its counterpart, **Redundancy**, 1 - H_i /H_{max} is associated with banality. Other pairs such as periodic/aperiodic, informative/intelligible, unforeseeabble/foreseeable illustrate similar dichotomies [9].

In DISSCO, computations may involve up to two dozen sound parameters (degrees of freedom) whose values can be selected through random functions. It also supports the use of nested functions i.e. function parameters can be functions themselves. Calculating the entropy/information at each point where a random choice is available proves to be quite involved and Mote Carlo methods are used to estimate the probability distributions.

Evaluating Entity's metamorphosis during iterations also includes the Aesthetic Measure devised by George Birkhoff in the 1930s, another objective way to describe the experience [10].

$$M = \text{Order} / \text{Complexity} \quad (2)$$

While his theory was primarily notional, other mathematical interpretations of that idea have been proposed over the past few decades. For example, Bense propounded that the ideal aesthetic measure was the ratio between redundancy and information [11] while Machado and Cardoso claimed that it was a function of the ratio between Piece Complexity and Processing Complexity [12]. Although such algorithms were designed to be applied to visual art, similar designs can be applied to a computer music system as well. For this project, Order is interpreted as a ratio between the relative information delivered or the Originality of the message and its Redundancy while Complexity is defined as the number of possible choices (information entropy) together with the weighted number of methods used (hierarchical complexity).

$$H_i / H_m / (1 - H_i / H_m) * 1/n \text{ elements} + h_c \quad (3)$$

Another way of describing the project is to consider a musical work as a Complex Dynamic System akin in many ways to the Morphogenetic approach of Aurel Stroe [13]. Even uncomplicated compositions contain multiple competing or collaborating elements - pitch, rhythm, timbre, etc. - hence, a complex system. Morphogenetic music is a music in search of self-identity and Stroe uses the Catastrophe Theory developed by René Thom [14] to produce a music where processes and materials that are incommensurable coexist. It is a music seeking its own form.

DISSCO uses an Evolutionary Algorithm to model the human composition workflow, with the Aesthetic Measure acting as the fitness function. It deals with a piece of music in a state of flux, which changes its structure and sound attributes in order to maintain or approach a parameterized destination. When these changes are driven using Information Theory and Birkhoff's concepts, this model closely resembles the Create-Analyze-Modify workflow cycle of human music composition.

Controlling the evolution of the Entity-piece could also be tied to the fundamental architecture of the work, to its number of vertices and edges. In that case, the complete directed graph is established before the computations start but only a restricted number of vertices and their connected edges are used in the beginning Then, their number is gradually increased allowing the Entity to grow to maturity. This is followed by a reversal: the tree is "pruned" and let die thus simulating the existence of a living thing. The full, mature tree is constantly in the background, a sort of DNA of the composition, not always fully actualized. It determines the evolution of this Artificial Life-like Entity which is directed through the use of Information Theory and of the Aesthtic Measure.

It would seem that both by predetermining a value (constant or fluctuating) for Birkhoff's Measure, by foreordaining the growth and decay of the rooted graph tree and by continually evaluating the adherence to these objectives as they are reflected in the smallest details, a goal oriented course of action is set in motion. However, the process maybe derailed at any moment due to the randomness present at every step and controlling it means to maintain a precarious equilibrium between competing tendencies, a volatile, temporary balance and NOT a search for a stable, optimal solution. Like Sisyphus pushing a rock uphill only to have it fall down again and again, the Evolving Entity's renewal is an incessant struggle.

6. Conclusion: a world view

The Evolving Entity composition model is closer to the way humans actually compose: continuously refining the output through trial and error. It also reflects the natural world by creating the equivalent of a living organism which grows, develops, and transforms itself over time fulfilling thus the goal expressed by John Cage: " to imitate nature in its mode of operation". In the process, the role of the composer is changed from artisan - making distinctive objects in small quantities - to that of a *Demiourgos* who creates from scratch multiple Artificial Life-like Entities over which, however, it does not have immediate control.

These Entities belong to a world in which probability plays a major role but also a world anchored in deep and stable structures. The hierarchical tree architecture of DISSCO provides a solid template which spawns successive actualization. Together with the use of deterministic tools such as sieves and patterns, it constitute a base for accidental happenings which are governed at the detail level by probability functions. Yet, such random occurrences may exist only within the confines of the larger structure which is driven by causality. The parallel world of Evolving Entities becomes a partial reflection of the real world as it is described by science: ruled by indeterminacy at the particle level while large bodies obey the laws of classical mechanics. In the same way that chance happenings can not contradict the laws of Physics, the random mutations occurring during iterations can not be at variance with Entity's predetermined features.

In a project like the Evolving Entity, the play between determinism and indeterminacy, universal laws and hazard, or among destiny and free will can also be seen as the interaction between Being (sets, modulo and Boolean operations) and Becoming (random distributions, entropy/information). Using musical terms, one can also talk about static or "outside time" structures (directed graph, scales, meter, textures) and the dynamic, "in-time" realization of a piece driven by probability - to use the terminology employed by Xenakis in his "Formalized Music" [15].

7. References

1. W. Meyer-Eppler, "Statistic and Psychologic Problems of Sound", translated by Alexander Goehr, *Die Reihe 1 ("Electronic Music")*, 1957, pp. 55-61.Original German edition, as "Statistische und psychologische Klangprobleme", *Die Reihe 1 ("Elektronische Musik")*,1955, pp.22–28.
2. K. Stockhausen, *KlavierstückeXI Nr. 7,* Universal Edition, Vienna, Austria, 1956.
3. U. Eco, *The Role of the Reader*, Indiana University Press, Bloomington, IN, 1979. p. 48.
4. J. Scherer, *Le <<Livre>> de Mallarmé*, Galimard, Paris, 1978
5. K. Stockhausen, *Plus-minus Nr. 14*, Universal Edition, Vienna, Austria, 1863
6. https://www.moma.org/collection/works/79809, accessed October 27, 2019.
7. K.Stockhausen, *...how time passes...*, in die Reihe, Universal Edition, 1957; English version, Theodore Presser Co, Pennsylvania, 1959, pp. 10-40.
8. H. Brün, "Infraudibles", in *Music by Computers*, H. von Foerster and J. Beauchamp ed., John Wiley & Sons, New York, 1969, pp.117-121
9. A. Moles, *Information Theory and Esthetic Perception*, Univ. of Illinois Press, 1966, p. 63
10. G. D. Birkhoff, *Aesthetic Measure,* Harvard Univ. Press, 1933
11. M, Bense, "Einführung in die informationstheoretische Asthetik. Grundlegung und Anwendung". in *der Texttheorie*, Rowohlt Taschenbuch Verlag, 1969

12. P Machado, A. Cardoso, "Computing aesthetics", *Brazilian Symposium on Artificial Intelligence* (pp. 219-228). Springer, Berlin, Heidelberg, Springer, Berlin, Heidelberg, 1998, pp. 219-228
13. A. Stroe, C Georgescu and M Georgescu. "Morphogenetic Music", unpublished manuscript, Bucharest, cca. 1985
14. R. Thom, *Structural Stability and Morphogenesis: An Outline of a General Theory of Models*. Reading, MA: Addison-Wesley, 1989.
15. I. Xenakis, *Formalized Music*, Pendragon Press, Stuyvesant, NY, 1992, pp. 193-194